UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

DOCKET FILE COPY ORIGINAL

JAN 31 2005

RECEIVED

JAN 31 2005

Federal Communications Commission
Office of Secretary

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

Re: *Amendment of the Commission's Rules Regarding Maritime Automatic Identification Systems,* WT Doket No. 04-344, *Petition for Rule Making Filed by the National Telecommunications and Information Administration,* RM-10821.

Dear Ms. Dortch:

Enclosed please find an original and six (6) copies of reply comments of the National Telecommunications and Information Administration in the above-referenced proceedings. Please direct any questions you may have to the undersigned at (202) 482-1816.

Respectfully submitted,

Kathy Smith
Chief Counsel

Enclosures

Before the
Federal Communications Commission
Washington, DC 20554

RECEIVED

JAN 31 2005

Federal Communications Commission
Office of Secretary

In the Matter of	)	
	)	
Amendment of the Commission's Rules Regarding Maritime Automatic Identification Systems	)	WT Docket No. 04-344
	)	
Petition for Rule Making Filed by National Telecommunications and Information Administration	)	RM-10821
	)	
Emergency Petition for Declaratory Ruling Filed by MariTEL, Inc.	)	

REPLY COMMENTS OF THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

Michael D. Gallagher
Assistant Secretary for
Communications and Information

Kathy Smith
Chief Counsel

Fredrick R. Wentland
Associate Administrator

Edward Drocella
Division Chief, Spectrum Engineering and Analysis

Gary Patrick
Electronics Engineer

National Telecommunications and
Information Administration
U.S. Department of Commerce
Room 4713
1401 Constitution Avenue, N.W.
Washington, DC 20230
(202) 482-1816

January 31, 2005

Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of the Commission's Rules Regarding Maritime Automatic Identification Systems	)	WT Docket No. 04-344
	)	
Petition for Rule Making Filed by National Telecommunications and Information Administration	)	RM-10821
	)	
Emergency Petition for Declaratory Ruling Filed by MariTEL, Inc.	)	

REPLY COMMENTS OF THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

The National Telecommunications and Information Administration (NTIA) submits these reply comments addressing issues raised by MariTEL Inc.[1], RF Neulink[2], and Shipcom LLC[3] in their responses to the Federal Communications Commission (Commission) Memorandum Opinion and Order (MO&O) and Notice of Proposed Rulemaking (NPRM) regarding maritime Automatic Identification Systems (AIS).[4]

The United States Coast Guard (Coast Guard) has an operational requirement in support of homeland security to maintain maritime domain awareness. This is accomplished in part by establishing an AIS monitoring capability for locating and

---

[1] MariTEL Inc. Comments, WT Docket No. 04-344 (December 30, 2004) ("MariTEL Comments").

[2] RF Neulink Comments, WT Docket No. 04-344 (December 30, 2004) ("RF Neulink Comments").

[3] Shipcom LLC Comments, WT Docket No. 04-344 (December 30, 2004) ("Shipcom Comments").

[4] *See* Amendment of the Commission's Rules Regarding Maritime Automatic Identification Systems, *Memorandum Opinion and Order and Notice of Proposed Rulemaking*, WT Docket No. 04-344, RM-10921, FCC 04-207, 59 Fed. Reg. 65570 (November 15, 2004) ("NPRM").

identifying ships in all United States navigable waters.[5] In order for the Coast Guard to meet the requirements for maritime domain awareness, it is necessary for as many vessels as possible to be equipped with interoperable AIS devices. The Commission correctly recognized that to achieve this objective the international designation of Channels 87B and 88B must be adopted for AIS. Because AIS equipment on vessels entering United States navigable waters operate on both Channels 87B and 88B, both frequencies must be free of interference from other signals to ensure that the weakest signals can be detected.

Shipcom LLC encourages the Commission to ensure that appropriate AIS installation guidelines are applied.[6] We agree, but there is no need for additional Commission action because the USCG adopted field tested, internationally accepted installation guidelines as part of its AIS carriage regulations.[7]

MariTEL asserts that there is no identified need for forward error correction (FEC) and interleaving techniques in the normal maritime radio frequency environment.[8] By making statements such as this, MariTEL implies that its system is immune to signal fading and the resulting errors, which affect all mobile communications systems. Contrary to MariTEL's comments, the NL 6000 system, which is a representative Very High Frequency Public Coast (VPC) system that currently operates in the maritime environment, employs both FEC and interleaving. If these techniques were not necessary as MariTEL asserts, they would not be employed in the NL 6000 system. The fact is

---

[5] The term "navigable waters" as used herein is defined in 33 C.F.R. § 2.36(a).

[6] Shipcom Comments at 2.

[7] *See* 33 C.F.R. 164(a) note.

[8] MariTEL Comments at 25.

these techniques are necessary to provide a useful communications channel for mobile systems. The Commission should reject any arguments to the contrary.

MariTEL claims that the Joint Spectrum Center (JSC) study did not consider the critical variable of receiver desensitization in its model.[9] Desensitization is the impact of an off-tune interference signal (continuous wave or pulsed) on a non-linear device (*e.g.*, amplifier, mixer) resulting in a reduction of the gain of the circuit as well as cross-modulation effects. Pulsed desensitization can also cause after effects known as pulse stretching. The JSC's co-site analysis model and the measurement data used for creating the receiver database record used in the model included all of the above effects.

There were a number of technical issues raised in the Dorr Engineering Services Inc. (DESI) report that was part of the filing submitted by RF Neulink.[10] The DESI report addressed technical assumptions used in the JSC study submitted by NTIA.[11] The technical issues raised in the DESI report are primarily related to data throughput and the robustness of error correction codes to be employed in VPC receivers in the presence of AIS transmissions. The DESI report ignored the use of erasure in both their analysis and the modified VPC receiver.[12] Incorporation of erasure capability is a common technique for increased robustness in Reed Solomon (RS) error correction techniques. Erasure was considered in the JSC report, but the system analyzed by DESI and which it referred to as

[9] *Id.* at n 70.

[10] *See* Attachment to RF Neulink Comments.

[11] Joint Spectrum Center, Department of Defense, *EMC Analysis of Universal Automatic Identification and Public Correspondence Systems in the Maritime VHF Band* (February 2004).

[12] An erasure is like taking a pencil eraser and erasing a letter in a word. The letter that should be in that position is unknown but the position of the erasure is known. If the position of the error is known, error correction techniques such as Reed Solomon are more effective in correcting the errors and add robustness to the system.

the JSC-suggested system did not include erasure capability. Erasure capability comes at a cost of a slightly more complex processor. However, there is no increase in bandwidth or delay required. In fact, there is no difference between the transmitted waveforms of a RS with erasure capability and the signal without erasure capability. A more detailed discussion of the technical issues raised in the DESI report is provided in Enclosure 1 of Attachment A.[13] In that document, it is shown that a RS (31,19) code with an interleave depth of 16 codewords and employing a soft decision process is more than adequate to correct the effects of both AIS transmissions and VPC signal fading.

MariTEL additionally asserts that the use of simplex operations in a duplex channeling scheme is particularly disruptive.[14] MariTEL has known that AIS operates on a wideband, simplex default basis for a long time, including during the negotiations for its Memorandum of Agreement (MOA) with the Coast Guard, but it did not object. These negotiations and the MOA preceded MariTEL's decision to abandon its voice operations by June 6, 2003, for its planned data service. MariTEL's late objection to simplex operations is untimely and impractical. More important, requiring switching of channels would unnecessarily increase the possibility of collisions and increase the difficulty of using AIS for maritime domain awareness. Thus this objection fails for the same reason that all MariTEL's objections to the NPRM fail. The Commission's decision to allocate channels 87B and 88B for congressionally mandated AIS operations best serves the public interest because it maximizes the benefits to maritime safety and

[13] Attachment A is a letter dated January 31, 2005 from B. Judge, Captain, U.S. Coast Guard, Chief, Office of Claims and Litigation (by direction of the Commandant) to Frederick R. Wentland, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration.

[14] MariTEL Comments at 28.

homeland security while minimizing the impact of AIS operations on MariTEL's operations on its remaining VPC licensed frequencies.

Paragraph 15 of the NPRM contains a request for comments regarding whether inland Very High Frequency Public Coast Station Area (VPCSA) licensees should be able to broadcast on channel 87B. The Coast Guard notes that a number of navigable waters are located on inland VPCSAs and that vessels navigating these waters may be subject to AIS carriage requirements as well. A list of these navigable waters and the VPC designations are provided in Enclosure 2 of Attachment A. This further supports the requirement for a nationwide allocation of AIS for both Channel 87B and 88B.

NTIA hereby submits the foregoing reply comments and requests the Commission to take actions consistent with the views expressed herein.

Respectfully submitted,

Kathy Smith

/Kathy Smith
Chief Counsel

Michael D. Gallagher
Assistant Secretary for
Communications and Information

Fredrick R. Wentland
Associate Administrator

Edward Drocella
Division Chief, Spectrum Engineering and Analysis

Gary Patrick
Electronics Engineer

National Telecommunications and
Information Administration
U.S. Department of Commerce
Room 4713
1401 Constitution Avenue, N.W.
Washington, DC 20230
(202) 482-1816

January 31, 2005

U.S. Department of Homeland Security
United States Coast Guard

Commandant
United States Coast Guard

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: CG-622
Phone: (202) 267-2860
Fax: (202) 267-4106
Email:

2400

JAN 3 1 2005

Frederick R. Wentland
Associate Administrator, Office of Spectrum Management
National Telecommunication and Information Administration
Herbert C. Hoover Building
14th and Constitution Ave
Washington DC 20230

Dear Fred:

Thank you for filing comments to the FCC on our behalf supporting the nationwide allocation of 161.975 and 162.025 MHz for AIS under docket WT No. 04-344. The following are in reply to technical issues raised in comments filed by MariTEL, Neulink and Shipcom.

MariTEL asserts that the Commission trivializes the impact of introducing coding and interleaving on MariTEL's plan to implement a data offering. Rfneulink concludes that forward error correction (FEC) and block interleaving is not an effective engineering solution to mitigate AIS interference. Both further criticize Joint Spectrum Center for ignoring the effects of receiver desensitization in their earlier analysis. At the Coast Guard's request the Joint Spectrum Center, the Department of Defense's center of excellence for electromagnetic spectrum management, analyzed MariTEL and Rfneulink's criticism. Their response explains that their model and measurement data considered the impact of receiver desensitization and refuted Rfneulink conclusion that error correction would reduce throughout unacceptably and to fail to be robust enough to correct effects of AIS pulses and fading. The Joint Spectrum Center further noted that Rfneulink's analysis of its report contained certain erroneous assumptions. The Joint Spectrum Center again concluded that FEC and block interleaving can adequately mitigate the impact of AIS without a harmful impact on throughput. See Enclosure 1.

This issue concerning interference to data communications is not new. The International Telecommunications Union addressed the same problem over two decades ago when it developed digital selective calling (DSC) for distress alerting[1] on 156.525 MHz. Under the Global Maritime Distress and Safety System, ships are expected to receive DSC calls while other VHF shipboard radios are transmitting on adjacent channels. To alleviate the problem of interference to DSC, as well as to overcome fading, problems similar to the ones MariTEL faces, ITU specified DSC include FEC using 50 ms interleaving. The JSC report and analyses, as well as ITU's development of digital selective calling, show that AIS need not interfere with a VHF data system operating over channels which the Commission auctioned to MariTEL.

MariTEL additionally asserts that the use of simplex operations in a duplex channeling scheme is particularly disruptive. Yet MariTEL has long known that AIS uses simplex operations on a difficult-to-change default basis. MariTEL was a regular participant in early meetings of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) developing AIS standards, and therefore was well aware of, and did not object to, the decision to

[1] ITU-R Rec. M.493 (series)

adopt simplex operations as the default basis for AIS. Similarly, although wideband, simplex operations of AIS were substantially discussed during the Memorandum of Agreement negotiations, MariTEL in the end did not object to its use, nor did they object to the letter forwarding the MOA to the FCC which clearly stated that AIS would employ wideband, simplex operations. Additionally, MariTEL never expressed any concerns about the impact of wideband, simplex operations on its own operations during the subsequent AIS frequency coordination meetings required by the MOA. MariTEL's late objection to the internationally accepted industry standard is untimely, and its alternative solution is at best, impractical. More important, switching channels amplifies the opportunity for operator error and confusion, unnecessarily increasing the possibility of collisions and increasing the difficulty of using AIS for maritime surveillance. Furthermore, it doesn't eliminate the operation on these default channels by vessels outside the United States territorial seas whose transmissions could even reach inland locations, nor the requirement that these channels be clear to allow their monitoring on shore.

Shipcom LLC encourages the FCC to ensure that appropriate AIS installation guidelines are applied. The Coast Guard agrees, and has in fact adopted field tested, internationally accepted installation guidelines as part of its AIS carriage regulations.

In addition to these technical issues, the Coast Guard has determined that there are certain navigable waters located in the inland VPCSA's. See Enclosure 3. This list is not exhaustive, and other navigable waters may be located in the inland VPCSA's. This information relates to the FCC's request for comments in paragraph 63 of the NPRM regarding whether inland VPCSA licensees should be able to broadcast on channel 87B. Vessels navigating on these waters may be subject to AIS carriage requirements as well.

Even if MariTEL's technical objections had merit — which they do not — the public interest is best served by a nationwide designation of channels 87B and 88B for AIS. That allocation maintains uniformity with the international maritime community and maximizes the maritime safety and homeland security benefits of AIS with the minimum impact to MariTEL.

I hope that this information helps clarify and resolve any concerns raised by MariTEL about potential interference between AIS operations and operations on the other VPC channels. If the Coast Guard can be of further assistance in this matter, please let us know.

Sincerely,

B. JUDGE
Captain, U. S. Coast Guard
Chief, Office of Claims and Litigation
By direction of the Commandant

2 Enclosures

DEFENSE INFORMATION SYSTEMS AGENCY
JOINT SPECTRUM CENTER
2004 TURBOT LANDING
ANNAPOLIS, MARYLAND 21402-5064

IN REPLY REFER TO: Joint Spectrum Center (J8)

JSC/J8-05/027
27 JAN 2005

MEMORANDUM FOR US COAST GUARD, SPECTRUM MANAGEMENT DIVISION
ATTN: MR. JOE HERSEY

SUBJECT: Clarifications of AIS Analysis

Reference: USCG E-mail, "RF Neulink Technical Report, 5 January 2005"

1. Enclosed, as requested in the above reference, is the Joint Spectrum Center (JSC) response to the Maritel, RF Neulink and Dorr Engineering Services filings with the FCC on 30 December 2004. This memorandum provides comments and clarifications on the use of soft decision decoding with forward error correction to effectively mitigate interference from Automatic Identification System transponders.

2. The JSC point-of-contact is Mr. Robert Lynch, JSC/J8, telephone (410) 293-2681.

DAVID A. GAINES, Lt Col, USAF
Chief, Acquisition Support Division

Enclosure:
Comments on Maritel, RF Neulink and Dorr Measurement Report

ENCLOSURE( )

DISTRIBUTION LIST

External	No. of Copies
US Coast Guard, Commandant (CG-622) Chief, Spectrum Management Division ATTN: Mr. Joseph D. Hersey, Jr. 2100 Second Street, SW Washington, DC 20593-0002	1
Internal	
J8/R. Lynch	1
DWA/W. Whittington	1
DWA/M. Roberts	1

Comments on Maritel, RF Neulink and Dorr Measurement Report

A number of issues were raised in the RF Neulink/Dorr ESI and Maritel comments filed with the FCC on 30 December 2004. Several of these issues are addressed here. These issues relate to the adequacy of the JSC analysis with respect to receiver desensitization and to JSC proposals to employ enhanced error correction to mitigate AIS effects. The proposed mitigation was stated by Dorr to reduce throughput unacceptably and to fail to be robust enough to correct effects of AIS pulses and fading. As will be seen below, neither appears to be true.

ADEQUACY OF THE JSC ANALYSIS WITH RESPECT TO DESENSITIZATION

In Maritel's filing, footnote 70, Maritel Inc. claims that the JSC study did not consider the critical variable of receiver desensitization in its model. Desensitization is the impact of an off-tune interference signal (CW or Pulse) on a non-linear device (e.g. amplifier, mixer) resulting in a reduction of the gain of the circuit as well as cross-modulation effects. Pulsed desensitization can also cause after effects called pulse stretching. The JSC's COSAM model and the measurement data used for creating the receiver database record used in the model included all of the above effects.

SUMMARY OF THE RF NEULINK/DORR REPORT

The Dorr document reports the measured results obtained with an NL6000 receiver and provides additional analysis and conclusions. The receiver presently employs a (31, 19) Reed Solomon (RS) code with an interleaving depth of 6 codewords. Interleaving depths of 6 and 16 codewords were used in their testing and analysis. On page 4, the Dorr report calculates the maximum pulse width that can be tolerated so as to produce zero errors. The tolerable effective interference pulse width is given as 8.16 ms for a depth of 6 codewords and 21.7 ms, if a depth of 16 codewords is assumed.

We agree that neither would be adequate for mitigation of AIS. RS error correction codes are capable of correcting data in the presence of either interference bursts or fades as long as the duration of both during a frame does not exceed a value determined by the code parameters.

Below, we provide the tolerable pulse width for six cases: a (31, 19) code with depths of 6, 12, and 16 codewords for both hard-decision and erasure-capable. Ignoring the apparent typo,* our results agree with theirs if hard decision decoding is used. However, the results JSC analysis used soft decision decoding, as explained below.

CODE ROBUSTNESS

BASIC DATA

The system RF-channel bit rate is 22.05 kilobits per second. The FSK symbol rate is 11.025 kilo-symbols per second. The dimensions of a single codeword are 31 RS symbols in all cases. There are 5 binary bits in a RS symbol, yielding 155 bits per codeword. Thus the duration of a RS codeword is effectively 7.03 ms (obtained from 155 bits/22050 bits per second).

* where Dorr incorrectly states that the code is (31, 6) (instead of (31, 19) with an interleaving depth of 6 codewords

ROBUSTNESS OF (31, 19) CODE WITH DEPTH OF 6

The present NL6000 employs a hard-decision RS code with an interleaving depth of 6 codewords. For a (31, 19) code with a depth of 6 codewords, a frame contains 31x6=186 RS symbols or 186x5=930 bits. Thus a frame duration is (930/22050) = .042177 seconds. There are 31 – 19 = 12 parity symbols per codeword and 12 x 6 = 72 parity symbols per frame, or 72x5=360 parity bits. A RS code employing hard decision can correct an error burst equal in duration to ½ of the number of parity symbols, 180 bits in this case. Thus a tolerable burst duration is (180/22050) = .008163 seconds or 8.16 ms. If soft decision is employed (usually termed as erasure capable) a burst equal to twice the number of parity symbols during a frame can be corrected error free. In this case the burst can be 16.33 ms.

ROBUSTNESS OF (31, 19) CODE WITH DEPTH OF 12

For a (31, 19) code with a depth of 12 codewords, a frame contains 31x12=372 RS symbols or 372x5=1860 bits. Thus a frame duration is (1860/22050) = .084354 seconds. There are 31 – 19 = 12 parity symbols per codeword and 12 x 12 = 144 parity symbols per frame, or 144x5=720 parity bits. A RS code employing hard decision can correct an error burst equal in duration to ½ of the number of parity symbols, 360 bits in this case. Thus a tolerable burst duration is (360/22050) = .01633 seconds, or 16.33 ms. If soft decision is employed (usually termed as erasure capable) a burst equal to twice the number of parity symbols during a frame can be corrected error free. In this case the burst can be 32.65 ms.

ROBUSTNESS OF (31, 19) CODE WITH DEPTH OF 16

For a (31, 19) code with a depth of 16 codewords, a frame contains 31x16=496 RS symbols or 496x5=2480 bits. Thus a frame duration is (2480/22050) = .11247 seconds. There are 31 – 19 = 12 parity symbols per codeword and 12 x 16 = 192 parity symbols per frame, or 192x5=960 parity bits. A RS code employing hard decision can correct an error burst equal in duration to ½ of the number of parity symbols, 480 bits in this case. Thus a tolerable burst duration is (480/22050) = .02177 seconds, or 21.77 ms. If soft decision is employed (usually termed as erasure capable) a burst equal to twice the number of parity symbols during a frame can be corrected error free. In this case the burst can be 43.54 ms.

CONCLUSIONS REGARDING RS ROBUSTNESS

RS codes are capable of correcting data in the presence of either interference bursts or fades as long as the duration of both during a frame does not exceed a value determined by the code parameters. A (31, 19) RS code with erasure capability and with an interleaving depth of either 12 or 16 codewords will be sufficient to correct AIS pulses and have enough margin to provide at least the same protection against fades as the present design. Note that the present NL6000 can correct for combined bursts and fades of duration of about 8 ms. (See analysis above for a (31, 19) code with a depth of 6.)

On the other hand, if an erasure-capable code with a depth of 16 is employed, the correction capability is increased to durations of about 43 ms. Thus, subtracting the 8 ms capability presently available, a more than sufficient 35 ms remains to remove AIS pulses. The conclusion is that after correction of AIS effects an even greater immunity to fading would be provided.

The Dorr report ignored the use of erasure in both their analysis and modified receiver. Erasure is a common technique that doubles the duration of burst tolerance. Erasure was assumed in the JSC final report, but the system analyzed by Dorr, which he called the JSC-suggested system, did not include erasure capability.

DESIGNING AN ERASURE CAPABILITY

Incorporation of erasure capability is a common technique for increased robustness in Reed Solomon error correction. It is well known technique to double the burst duty cycle that the RS can correct.[1] The JSC has developed and validated mathematical models of such systems. [2] Erasure capability comes at the cost of a slightly more complex processor. No increase in bandwidth or delay is required. In fact, no difference exists between the transmitted waveforms of a RS with erasure system and one without erasure capability.

The NL6000 radio employs 4-ary frequency shift keying (FSK). The binary data is grouped into bit pairs. Four possible bit sequences result for any given pair, termed FSK. A carrier is modulated with one of four tones to represent a bit pair. A bank of four frequency filters, one for each possible tone, receives the transmitted signal. When the signal to noise ratio is high, the output of one of the filters is much higher than the others. When the signal to noise ratio is low, the output of the filter with the highest voltage will generally be close in value to the output of the filter with the next highest value, and the received bit pair is deemed to be "low-quality." In the present system, a RS symbol consists of a group of 5 bits. As a simple example, an erasure capability might involve tagging a RS symbol for erasure if some number of the 5 bits is low-quality. The RS processor then considers that symbol erasure when it determines the minimum (Hamming) distance between the received codeword and each codeword in the set of possible transmitted codewords.

PACKET PREAMBLE AND SYNCH-WORD IMPACT

Each data packet includes a preamble and synchronization codeword, which are more susceptible to high-level bursts than the rest of the packet which is protected by the interleaving of RS symbols. Because of this, even one 3 ms high-level pulse can cause synchronization loss and the entire data packet to be lost if the pulse overlaps the 7.03 ms synch codeword. The duration of the preamble and synch is estimated to be approximately 15 ms as compared to the total packet duration of, say, 350 ms. Thus, making the rest of the packet immune to high-level bursts can make the system effectively immune to AIS bursts. This is examined using an example given in the RF Neulink/Dorr report.

The example is given on pages 7 & 8 of the Dorr report. They call it a situation representing the "largest impact" of AIS: when the base is broadcasting a message such as a weather report. The message consists of 200 packets of 500 bytes each. Each packet lasts about 350 ms. An interleaving frame depth of 16 codewords was assumed. No acknowledgements are used in such broadcasts; meaning individual packets with errors[3] are not retransmitted when requested and those packets cannot be corrected until the next transmission 70 seconds later, or on following transmissions.

The procedure follows.

1. **Determine the number of codewords needed per packet:** The packet payload is 500 8-bit bytes or 4000 bits. This requires 800 of the 5-bit RS symbols. Each (31, 19) codeword carries 19 data (RS) symbols. Thus 43 codewords are needed per packet.
2. **Determine the number of interleaving frames needed per packet:** Since 16 codewords are carried per frame, 43 codewords requires 3 frames.
3. **Determine the number of bits in a frame:** There are 16 codewords of 31 RS symbols with 5 bits each for 2,480 bits per frame.

[1] For example, see the text by Michelson & Levesque, *Error Control Techniques for Digital Communication,* specifically Section 5.7, John Wiley & Sons, Inc., 1985.
[2] Models for the radios in the Joint Tactical Information Distribution System are one example. The JSC uses such models to evaluate the performance of systems in highly congested electromagnetic environments.
[3] Packet errors are detected by the Cyclic Redundancy Check (CRC)

4. **Determine the duration of three frames:** For a transmission bit rate of 22.05 kilo-bits per second, the frame duration is about 112.5 ms. Since a packet consists of 3 frames the required duration is about 337.5 ms. Overhead, including the preamble is assumed to extend the duration to about 350 ms, the duration stated in the Dorr report.

Consider the worst case of 2-second intervals between AIS pulses. The probability of AIS pulse (about 27 ms) intersection of a 350 ms packet is (0.350 + 0.027) seconds divided by 2.0 seconds or approximately 19%. The Dorr report indicates 17.5%. Dorr's Table 4 indicates 6 transmissions are required to achieve 99% probability of reception under these conditions.

However, if the interleaved data is immune to AIS pulses (due to the robustness of the erasure capable RS (31, 19) depth 16 code), only the intersection of the approximately 15 ms preamble and synch word is pertinent. The probability of AIS pulse (about 27 ms) intersection of a 15 ms packet is (0.015 + 0.027) seconds divided by 2.0 seconds or approximately 2%. Under these conditions only 4 packets (2% of the 200 packets) are expected to be lost. These will be identified via the CRC and replaced with high probability on the second retransmission, the expected number of packets in error on the reception of the second retransmission being <<1.

THROUGHPUT COMPARISON

While the use of forward error correction reduces throughput, it is believed that broadcast throughput will not be as low as the Dorr report states when erasure capability is used. The present NL6000 receiver employs a common forward error correction scheme, which is effective against fading. Fades are short periods when the desired signal drops in level below the receiver noise. The data that exists during that period is not received and without error correction information is lost until it can be resent. Forward error correction involves sending the data in groups of symbols called codewords that contain redundancy. The codeword can be correctly deciphered as long as the number of symbols containing bits in error does not exceed a threshold.[4] The cost of this redundancy is lower throughput. A RS (31, 19) codeword for example contains 31 symbols only 19 of which are the original information and 12 redundant symbols. The code rate or efficiency of these codeword is 19/31 or 0.613. This rate reduction reduces throughput.

Given a long burst of noise during a codeword, beyond what is tolerable, followed (or preceded) by a number of codewords free of such noise bursts, symbol interleaving among the codewords still permits the error-free correction of the codewords. That is why the present system employs an interleaver with a "depth" of 6 codewords. This means that a set of 6 codewords is transmitted together. This set is called an "interleaving frame." The depth or frame size is usually set based on the fading environment; statistics of durations and frequency of fades are considered. Larger frame sizes can tolerate longer fades, but the improvement tends to diminish with larger size. JSC has proposed increasing the depth but keeping the same codeword (31, 19). Thus the codeword size and code rate would remain the same.

The AIS pulses occur at a minimum interval of 2 seconds. A NL6000 codeword lasts about 7 ms. Thus there are at least 285 codewords between codewords experiencing an AIS pulse. Using an interleaving depth of 6, symbols experiencing an AIS pulse are spread over 6 codewords, meaning a reduction by 1/6 of the maximum symbol errors in a codeword. This reduction would continue with increasing depth until the depth reaches 285 codewords. JSC modeling has determined that a (31, 19) code with erasure capability and a depth of 12 would eliminate errors due to AIS pulses. A depth of 16 would not only eliminate AIS pulses, but also provide better robustness in fading. Because of this it is believed that an analysis of throughput, taking into consideration the reduced requirements for packet repeat requests due to fading, might show an increase in throughput when compared to the present system.

---

[4] The threshold for incorrect symbols can be doubled with the use of Reed Solomon decoding with erasure capability at no cost to throughput.

BODY OF WATER	GEOGRAPHIC AREA
Arkansas River, CO	VPC 24
Navajo Reservoir, CO	VPC 38
Platte River, CO	VPC 25
Bois de Souix River, MN	VPC 10
Red River of the North, MN	VPC 10
Upper Mississippi River, MN	VPC 10
Lake of the Woods, MN/Canada	VPC 10
Platte River, NE	VPC 15
North Platte River, NE	VPC 15, 26
Animas River, NM	VPC 40, 42
Lake Navajo, NM	VPC 23
Rio Chama, NM	VPC 23
San Juan River, NM	VPC 23, 38
Lake Metigoshe, ND	VPC 10
Little Muddy River, ND	VPC 11
Missouri River, ND	VPC 11, 12
Upper Des Lacs Lakes, ND	VPC 11
Red River, OK	VPC 16
Cheyenne River, SD	VPC 13, 14
Missouri River, SD	VPC 13
Cuevas Creek, TX	VPC 18
Lake Amistad, TX	VPC 18, 19
Rio Grande, TX	VPC 18, 19, 40
Big Horn River, WY	VPC 27, 28
North Platte River, WY	VPC 26, 27
Lake Tahoe, CA/NV	VPC 34
Lake Mead, AZ/NV	VPC 36
Lake Powell, AZ/UT	VPC 37

ENCLOSURE(2)